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Correlation of urban avian species diversity present in heterogeneous habitat types of Berhampur city, Odisha, Eastern India

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Abstract
This study was conducted for the first time in order to know the urban avian species diversity and their correlation among four habitat types *viz*. agricultural lands, human settlements, forest patches and wetlands present in Berhampur city, Odisha, Eastern India. Altogether 16 sampling points (4 points in each habitat type) were studied from November 2019 to October 2021. A total of 88 bird species were identified in 18 orders, 43 families and 72 genera. ANOVA revealed the abundance of birds among habitats varied significantly [$F(3, 348) = 3.91$, $p < 0.05$]. Agricultural land was the most Speciose habitat (66 species, 1079 individuals). Insectivore birds dominated (34%), followed by a carnivore (16%). Avian species diversity of agricultural land with human settlements, forest patches ($r = 0.46$, $r = 0.53$, $p < 0.05$) and human settlement with forest patches ($r = 0.52$, $p < 0.05$) is highly correlated.

Keywords: Avifauna, birds, Berhampur, checklist, species abundance, species richness

Introduction
Birds are one of the main ecological indicators, proxy taxa and an integrative part of any ecosystem in order to know its overall health and wealth [1]. Investigating the spatiotemporal assemblage pattern across various organized habitats in the urban ecosystem is one of the basic trends in urban avian species diversity (UASD) related studies, which are increasing recently. It helps in understanding the current scenario of UASD loss and then in implementing the mitigative measures for counteracting. Natural factors like seasonality, weather parameters, availability of food, shelter, breeding ground and some anthropogenic factors like noise pollution, irregular and uncontrolled waste disposal, the establishment of transport corridors, residential and market complexes, habitat alteration are the main reason for the changes in the spatiotemporal distribution of urban avian community (UAC) [2-5]. The green patches of any urban area generally consist of moderate forest patches, parks, gardens, grasslands and wetlands with aquatic vegetation, woody vegetation, and human settlements are the major supporters of holding the urban avian community across various habitats in the urban ecosystem [6, 7]. The focus of some avifaunal diversity studies has greatly shifted towards the highly urbanized city and towns rather than sticking to specific protected areas nowadays because the UAC can be greatly influenced by the factors mentioned above, which results in the local extinction of rare bird species as well as the population downfall of some bird species [8]. UrThe urban ecosystem also helps settle some bird species, which greatly alters the regional biodiversity and UAC composition. Hence, studying them in the urban ecosystem is becoming essential due to the increased anthropogenic disturbances along with urban landscapes [9-11].

Keeping this context, the UASD of Odisha has received less attention from the researchers. Because mostly, the research works on avian species diversity have been sporadic and restricted to several protected areas [12-16]. Only a few noteworthy studies could be reviewed on habitat use by the UAC of Bhubaneswar city and the factors influencing their assemblage pattern across various habitats [11, 17].

But there has been no research work on the UASD of Berhampur city, situated in the Ganjam district of Odisha. It is also called the 'Silk City of Odisha' and is one of the major cities in southern Odisha. This city is the epicenter for art, education, health facility, trade, transportation and urbanization. Hence the present study is aimed to document the first-ever information on the avifaunal diversity present in and around the Berhampur city.

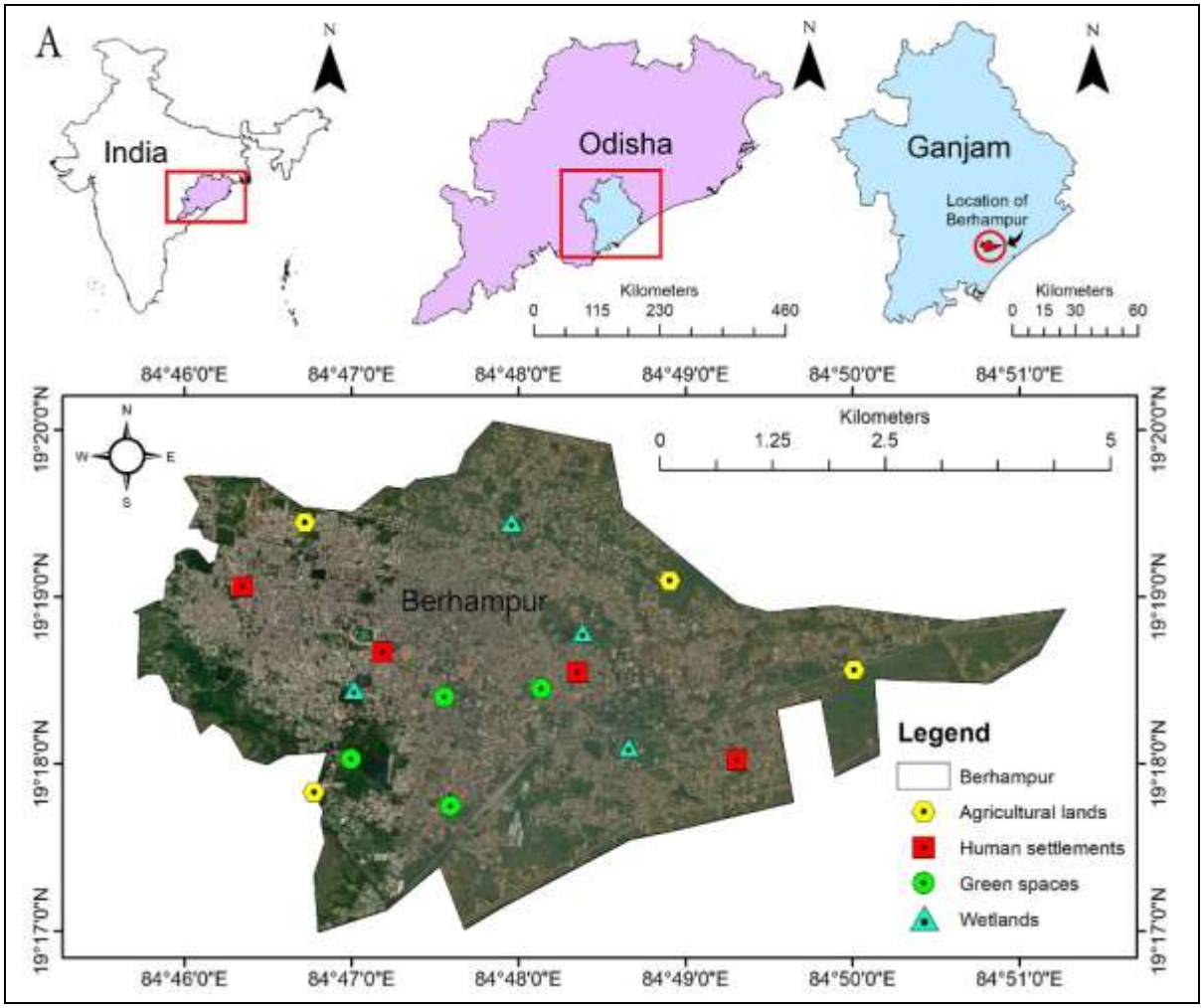
This study also tries to explain the causes of correlation among UASD across various habitat types present in this huge urban landscape by comparing the avian species richness and their abundance.

Materials and Methods

Study area

The Silk city is located in the Ganjam district and on the southern side of Odisha (19.3338°N, 84.8419°E (Fig 1). It is one of the fastest-growing cities with a population of 0.35 million with an area of 79.6 sq. km. The elevation ranges from 26m to 45m. Vegetation of this city is mainly dominated by plant species *viz*. *Annona reticulata*, *Argemone mexicana*, *Caesalpinia pulcherrima*, *Cassia fistula*, *Delonix regia*, *Eucalyptus* sp., *Ficus benghalensis*, *F. religiosa*, *Ixora coccinea*, *Magnolia champaka*, *Mangifera indica*, *Manilkara zapota*, *Musa* sp., *Polyalthia longifolia*, *Psidium guajava*, *Tamarindus indica*, *Tectona grandis*, *Terminalia arjuna*, *Ziziphus mauritiana* [18]. Three distinct seasons can be experienced in this city such as winter (November to February), summer (March to June) and monsoon (July to September). The temperature ranges from approximately 37°C during summer to 19 °C during the winter. The relative humidity is high during monsoon (95-98%) than in summer (70-76%) and winter (12-20%). The source of rain in this city is the south-western monsoon (July-September) and the average rainfall is 1190mm each year [19].

Topographically, the landscape of this city can be divided primarily into four kinds of habitats *viz*. (1) Agricultural lands (AG), where the main agricultural crops like *Oryza sativa*, *Vigna radiata*, *V. mungo*, *Cajanus cajan*, *Solanum tuberosom* are cultivated and the fields are surrounded with trees like *Cocos nucifera*, *Mangifera indica*, *Tamarindus indica*; (2) Human settlements (HS), which has larger area among all habitat types and is constituted primarily with smaller to larger urban structures like residential complexes, market complexes, medical complexes and other institutional campuses, complex road networks, over bridges, sewer systems; (3) Forest patches (FP) are the green spaces like parks, gardens, orchards, small forest patches present inside the city with the presence of the major woody tree species mentioned earlier and (4) Wetlands (WL) are mainly the small to large water bodies present inside this city along with smaller aquatic marshes, swampy patches with aquatic plants species like *Alternanthara* sp., *Ceratophyllum* sp., *Hydrilla* sp., *Ipomea* sp. and *Salvinia* sp. Four sampling points were selected under each habitat type, which means a total of 16 sampling points were selected for documenting the urban avian species diversity in and around Berhampur city. The details of the sampling points are given in Table 1.



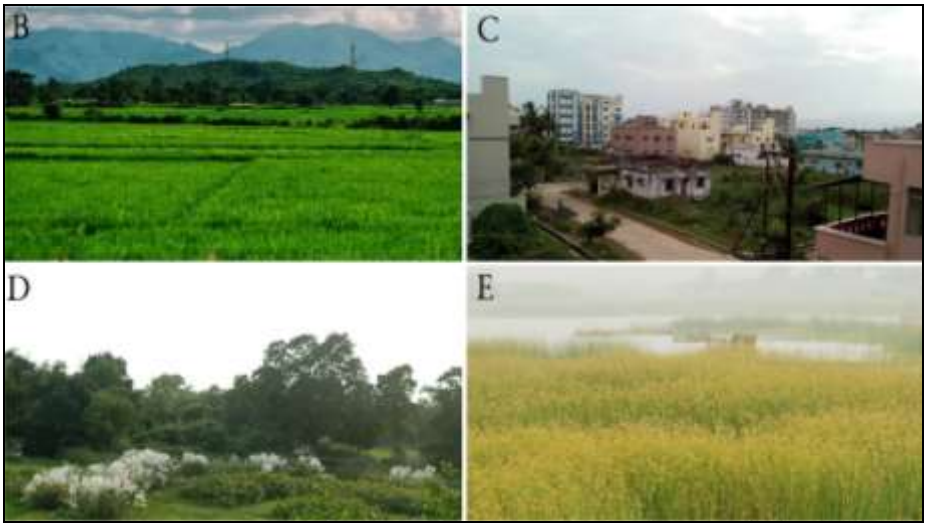


Fig 1: A. Map of 16 sampling points selected in Berhampur city under each habitat type; Types of habitats (B-E) selected inside Berhampur city. B. Agricultural lands (AG), C. Human settlements (HS), D. Forest patches (FP), E. Wetlands (WL).

Table 1: Details of the sampling sites selected in Berhampur city.

Sl. No.	Habitat types	Sampling points	Latitude (°C)	Longitude (°C)
1	Agricultural lands (AG)	Point 1	19.3183N	84.8151E
2		Point 2	19.3241N	84.7787E
3		Point 3	19.2972N	84.7796E
4		Point 4	19.3094N	84.8335E
5	Human settlements (HS)	Point 1	19.3092N	84.8059E
6		Point 2	19.3112N	84.7864E
7		Point 3	19.3177N	84.7724E
8		Point 4	19.3004N	84.8218E
9	Forest patches (FP)	Point 1	19.3005N	84.7833E
10		Point 2	19.3075N	84.8023E
11		Point 3	19.2598N	84.7932E
12		Point 4	19.3067N	84.7926E
13	Wetlands (WL)	Point 1	19.3017N	84.811E
14		Point 2	19.3131N	84.8064E
15		Point 3	19.3074N	84.7836E
16		Point 4	19.3241N	84.7993E

Data collection

Habitat-wise, field surveys were conducted from November 2019 to October 2021. Each sampling point was visited once in a week and the birds were observed during early morning hours (6:00 hrs-10:00 hrs) and during early afternoon hours (15:00hrs-18:00hrs). No surveys were carried out during heavy windy or heavy rainy days. Only point counts were done at each sampling point covering a 50m radius around the point using NIKON field binocular (8 × 40) and the birds were photographed using NIKON D5600 Digital SLR (Single Lens Reflex) camera with NIKON ED VR 70-300mm telephoto lens. But in the case of AG and WL, the distant point count method was followed [20]. Geo-coordinates of each point were measured using a GARMIN etrex 20 GPS (Global Positioning System) device. Few points were visited regularly to encounter maximum bird species. A number of individuals of each bird species sighted or heard by its call were noted down, but the call of the same species heard from two different directions on a sampling point was considered another individual. Photographed bird species were identified using available field guides [21-24]. Bird with only confirmed identification was included in this study. The commonness of each bird species was divided into three types *viz*. Common (C): the bird species which was encountered in every field visit or the abundance of bird species is more than 30; Fairly common (FC): if the bird species was sighted more often but not during every field visit or the abundance is between 11 to 30 and lastly Rare (R): if the bird species was not sighted more often and the abundance is less than 10. The residential status of each bird species was accessed as Resident (Re): bird species that breed in the study area; Local Migrants (LM): bird species which were found to produce outside of the study area and Winter Migrants (M): bird species that are not resident to the study area and sighted only during the winter season. Only one dominating or exclusive feeding guild was noted down for each bird species and categorized into Carnivore (feed on small reptiles, amphibians, mammals and dead remains); Frugivore (feed upon figs, several types of berries); Granivore (feeds on different types of seeds and grains); Herbivore (take herbs and macrophytes i.e. roots and stems of a plant as the core diet); Insectivore (mainly feeding on insects including butterflies, moths, grasshoppers, bees, wasps, earthworms, larvae, bugs, aquatic insects, beetles and other arthropods); Molluscivore (exclusively feed upon snails); Nectarivore (feeding on flower nectars and tree saps); Omnivore (take herbs, seeds as well as small insects, reptiles) and Piscivore (birds having different kinds of fishes as their primary diet). The habitat type of each bird species was determined in which the species mostly occurred. The threat category of every bird species was accessed and categorized according to IUCN Red List [25]. The detailed feeding guilds of birds across each habitat tyareere given in Table 2. This

information was compiled and provided in a final checklist (Table 4). The pre-requisite for determining the percentage of the categories of bird commonness, residential status, feeding guilds are available in the Zenodo repository via open access (https://doi.org/10.5281/zenodo.5855865).

Data analysis

The habitat-wise abundance was collected from all points and further subjected to further analysis the. Before data analysis the differences among avian species abundance of four habitats was analysed using ANOVA (Analysis of Variance) in Rstudio [26, 27]. The species rarefaction curve was plotted for each habitat type to check for overall sampling effort using PAST software version 4.04 [28,2 9] by taking the abundance dataset as a prerequisite (https://doi.org/10.5281/zenodo.5855865). The dataset related to species abundance of each bird species found in four habitat types was analyzed using the 'vegan' package of Rstudio software version 1.4.1106 to determine the following species diversity indices [27, 30].

(1) Shannon-Wiener diversity index (H'):

$$H' = -\sum_{i=1}^{s} pi \ln pi$$

Here pi is the proportion of ith species in the total sample. H' is defined by species richness (S) in the community and their evenness in abundance. It is the sum of a total number of species within a habitat with the relative abundance of each species [31,32]. A larger value of H' depicts that the habitat is more diverse than others.

(2) Simpson's diversity index or index of dominance (λ):

$$\lambda = \sum (ni\,(ni-1)/\,N\,(N-1)$$

Here ni is the number of individuals and N is the total number of bird species found at each site. Since, this index is a probability, the value always lies between 0 and 1. This index generally predicts that if two individuals are drawn randomly from an infinitely large community, then those two individuals will be of different species [33]. Like H', the larger value of λ means a more diverse habitat.

(3) Menhinick's index (D):

$$D = \frac{S}{\sqrt{N}}$$

Here S is species richness and N is the abundance [34]. A larger value means a more diverse habitat.

(4) Evenness index or Smith and Wilson's index (E):

$$E = \frac{\bar{H}}{LogeS}$$

Here, $\bar{H}$ is the value of the Shannon-Wiener index and S is the species richness of the respective habitat [35]. More the value of this index means, that the avian species are more evenly distributed in that habitat than in another habitat typeype.

The relative abundance (RA) of every bird order has been calculated using the following formula.

$$RA = \frac{\text{total number of individuals present in an order of bird}}{\text{total number of bird individuals found in our entire study area}} \times 100$$

The entire result of this analysis is given via the following link https://doi.org/10.5281/zenodo.5855865.

Similarity among four habitats was checked by the Bray-Curtis similarity index using PAST software [29]. Pearson's correlation coefficient was calculated among habitats to determine the commonness of UASD using the 'corrplot' package of Rstudio software [11, 17, 36]. The habitats were considered a dependent variable and bird species present in that particular habitat were considered independent variables. All these analyses were estimated at 0.05 level of significance. The script for calculating the diversity mentioned above indices, ANOVA test and the correlation analysis is available in the Zenodo repository (https://doi.org/10.5281/zenodo.5855865).

Results and discussion

ANOVA reveaa led significant difference between the abundance of bird species of Berhampur among selected habitat types [F (3, 348) = 3.91, $p < 0.05$] The species rarefaction curve revealed that sampling has reached saturation in all habitats, so there is no need for sampling to find more species (Fig 2).

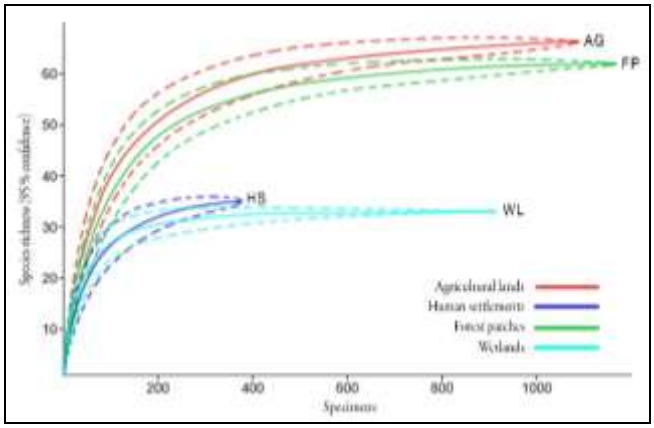


Fig 2: Species rarefaction curve of four habitat types of Berhampur.

Urban avian species richness and species abundance

A total of 88 bird species belonging to 18 orders under 43 families and 72 genera were identified. Among all the habitat types, AG is found to be more speciose (S = 66 species, 75% of total species found in Berhampur) than FP (S = 62, 71%), Human settlements (S = 35, 40%). WL was found to have the least number of species (S = 33, 37%) (Fig 3). Considering the total bird species abundance, AG has the highest number of individuals (N= 1079 individuals, 33.22% of total 3248 individuals) among all habitat types followed by WL (N= 915, 28.17%), FP (N= 876, 26.97%) and lastly HS (N= 378, 11.63%) (Fig 3). Ardeidae family was found to be dominating among all bird families having nine species (10% of the total bird species). Still, the order Passeriformes is the dominating order with 33 avian species (37% of the total bird species).

According to the commonness of avian species, 37 bird species (42% of total bird species) were common (CO), 19 species (21%) were fairly common (FC) and 32 species (37%) were rare species (R). Considering the residential status of bird species found in Berhampur, 68 bird species (77% of

total bird species) were resident (Re), 16 species (18%) were local migrants (LM) and only four species (5%) were found to be the migratory species (M) in Berhampur. The habitat-wise commonness of bird species and residential status of birds are given in Figure 4. Only three species *viz*. Oriental Darter Anhinga melanogaster, Black-headed Ibis Threskiornis melanocephalus and Alexandrine Parakeet Psittacula eupatria found in Berhampur city falls under the Near Threatened (NT) category of IUCN [20].

The feeding guild classification revealed that insectivore birds dominated with 30 species (34% of total bird species) followed by carnivore (n = 14 species, 16%), omnivore (n = 12, 14%), frugivore (n = 10, 11%), granivore (n = 9, 10%), piscivore (n = 8, 9%), herbivore and nectarivore (n = 2 each, 2%) and Molluscivore (n = 1, 1%) (Table 2). The difference among feeding guilds across four habitat types found non-significant [F (3, 32) = 0.975, p > 0.05].

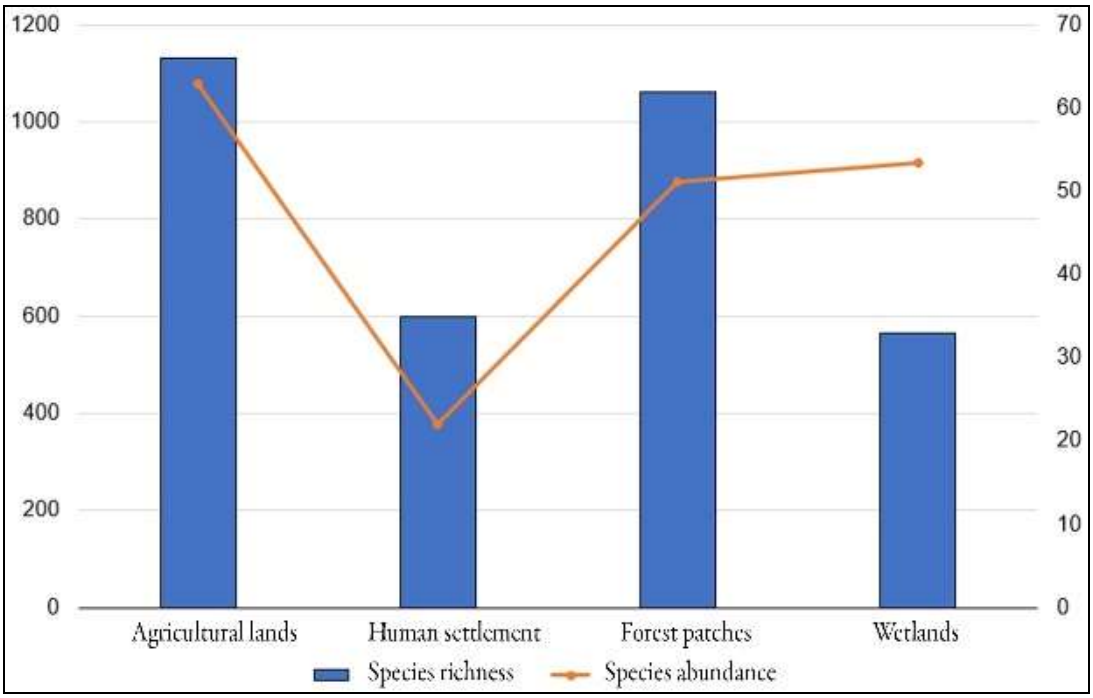


Fig 3: Avian species richness and abundance across four habitat types of Berhampur.

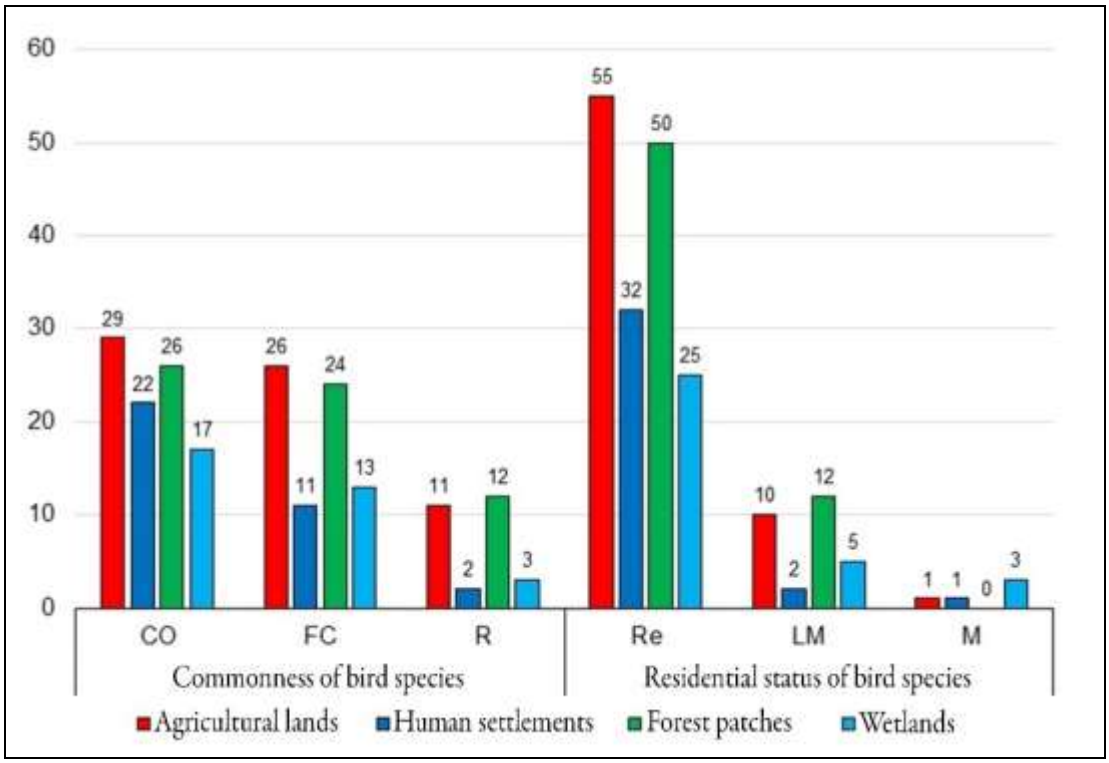


Fig 4: Habitat-wise bird species distribution according to commonness and residential status.

Table 2: Feeding guilds of birds found in four habitat types of Berhampur.

Feeding guilds	AG	HS	FP	WL	Berhampur
Carnivore	12	6	7	8	14
Herbivore	0	0	0	2	2
Frugivore	8	4	10	0	10
Granivore	9	4	9	0	9
Insectivore	24	13	25	6	30
Molluscivore	1	0	1	1	1
Nectarivore	2	2	2	0	2
Omnivore	7	5	6	8	12
Piscivore	3	1	2	8	8
No. of species	66	35	62	33	88

Bird species diversity indices and assemblage patterns

The calculated diversity indices (Table 3) among habitat types revealed that FP has the highest value of Shannon-Wiener index (H') = 3.78 followed by AG (H' = 3.66), WL (H' = 3.16). The least value of H' was calculated in HS (H' = 2.89). Similarly, the index of dominance (λ) was also found to be the highest in FP (λ = 0.97) than in other habitats. But the Menhinick's diversity index was found lower in WL (D = 1.09) and the highest value was calculated for FP (D = 2.09). The value the of evenness index has revealed that avian aquatic species are evenly distributed in WL (E = 0.71) followed by FP (E = 0.70), AG (E = 0.59) and the HS has more randomly distributed avian species. The related script of calculated diversity indices is availathe ble in Zenodo repository (https://doi.org/10.5281/zenodo.5855865).

Table 3: Calculated species diversity indices of four habitat types of Berhampur.

Diversity indices	AG	HS	FP	WL
Shannon-Wiener index (H')	3.66	2.89	3.78	3.16
Simpson's index	0.96	0.90	0.97	0.94
Menhinick's index	2.009	1.8	2.095	1.091
Evenness index	0.59	0.51	0.70	0.71

According to the relative abundance of different orders of the birds, species under orders Ciconiiformes (66.41%), Caprimulgiformes (60%), Falconiformes (66.66%), Columbiformes (55.6%) and Bucerotiformes (47.05%) were dominant in AG. In HS, Strigiformes order mainly was found (26%) followed by Passeriformes (21.48%), Bucerotiformes (17.64%) and Columbiformes (14.4%). The least abundant bird order is Gruiformes (2.11%) in HS. In FP, Psittaciformes (69.23%) dominate among other bird orders. Except this, orders like Cuculiformes (63.26%), Strigiformes (55.55%), Accipitriformes (46.15%), Bucerotiformes (35.29%), Caprimulgiformes (34.28%) are also dominant in FP. Species under the orders Anseriformes (100%), Podicipediformes (100%), Suliformes (100%), Gruiformes (77.81%), Pelecaniformes (64.23%) and Charadriiformes (53.84%) are most abundantly found in WL. The relative abundance of bird orders found in four habitat types of Berhampur is available in the Zenodo repository (https://doi.org/10.5281/zenodo.5855865). Photographs of the most abundant and rare bird species of all four habitat types are given in Figure 7.

Similarity among habitat types and the relationship between habitat and avian species diversity

The dendrogram based on the Bray-Curtis similarity index (Fig 5) showed that FP and AG have similar species diversity forming one cluster and HS is forming another cluster. Apart from all of these, WL doesn't show any similarity and forming a completely different cluster from the rest of the habitats.

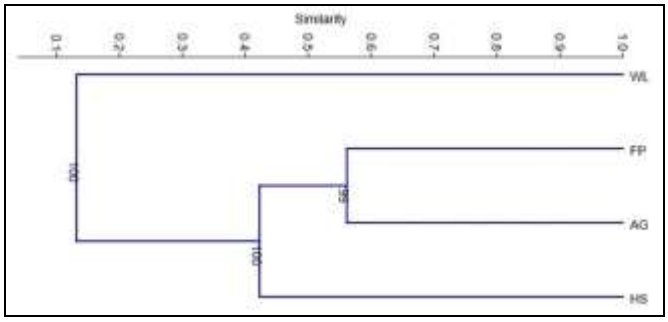


Fig 5: Dendrogram based upon Bray-Curtis similarity index showing similarity among four habitat types of Berhampur.

The correlation analysis was conducted among habitats, where species diversity was taken as independent variable and the dependent variable was taken as habitats (for the script see https://doi.org/10.5281/zenodo.5855865). This analysis revealed that bird species diversity of AG with HS, FP and species diversity of HS with FP is highly correlated (AG with HS: r = 0.46, p < 0.05; AG with FP: r = 0.53, p < 0.05; HS with FP: r = 0.52, p < 0.05) (Fig 6). Whereas the bird species diversity of WL with all three habitats were negatively correlated (WL with AG: r = -0.14, p < 0.05; WL with HS: r = -0.06, p < 0.05; WL & FP: r = -0.25, p < 0.05).

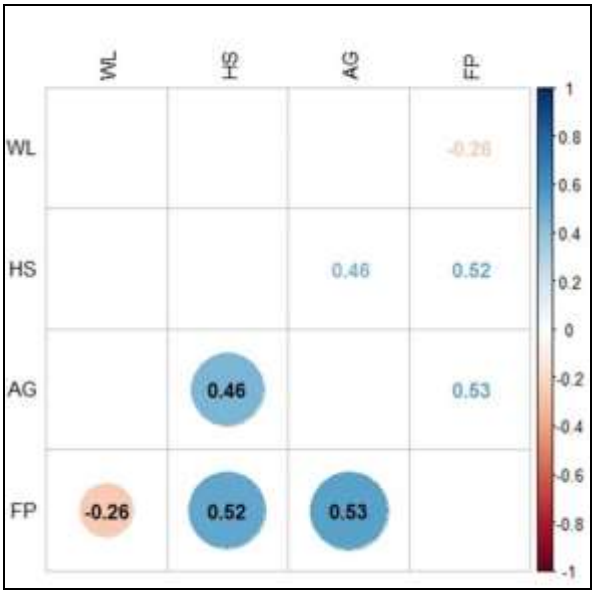


Fig 6: Correlation plot shows the relationship between species diversity of main habitat types in Berhampur city.

Fig 7: Photographs of the abundant and the rare bird species found in Agricultural lands (A-D) A. Laughing Dove *Spilopelia senegalensis*, B. Asian Openbill Stork *Anastomus oscitans*, C. Black-headed Ibis *Threskiornis melanocephalus*, D. Yellow wattled Lapwing *Vanellus malabaricus*; Human Settlement (E-H) E. Black Kite *Milvus migrans*, F. House Crow *Corvus splendens*, G. Oriental Magpie Robin (*Copsychus saularis*), H. Blue Rock Thrush *Monticola solitarius*; Forest Patches (I-L) I. Alexandrine Parakeet Psittacula eupatria, J. Rose-ringed Parakeet Psittacula krameri, K. Pied Bush Chat *Saxicola caprata*, L. Tricoloured Munia *Lonchura malacca*; Wetlands (M-P) M. Oriental Darter or Snake Bird Anhinga melanogaster, N. Grey-headed Swamphen Porphyrio poliocephalus, O. Pheasant-tailed Jacana *Hydrophasianus chirurgus*, *P. Cotton* Pygmy Goose *Nettapus coromandelianus*. Pictures credit: (A to G, M to P: Rajesh Lenka; H and L: Suchismita Sahu; I to K: Chinmayee Singh).

Table 4: Final checklist of birds found in Berhampur city. Commonness: CO (Common), FC (Fairly common), R (Rare). Residential status: Re (Resident), LM (Local migrant), M (Migrant). '* (NT)' donate the IUCN status 'NT' which is Near Threatened category.

Sl. No.	Family	Common name	Scientific name	abundance	Commonness	Residential status
Order Anseriformes						
1	Anatidae	Lesser whistling Duck	*Dendrocygna javanica*	80	CO	Re
2		Gadwall	*Mareca strepera*	32	CO	M
3		Cotton Pygmy Goose	*Nettapus coromandelianus*	59	CO	Re
4		Northern Pintail	*Anas acuta*	26	FC	M
Order Podicipediformes						
5	Podicipedidae	Little Grebe	*Tachybaptus ruficollis*	7	R	LM
Order Columbiformes						
6	Columbidae	Rock Pigeon	*Columba livia*	194	CO	Re
7		Laughing Dove	*Streptopelia senegalensis*	10	R	LM
8		Eurasian Collared Dove	*Streptopelia decaocto*	16	FC	LM
9		Spotted Dove	*Spilopelia chinensis*	31	CO	Re
Order Caprimulgiformes						
10	Apodidae	Asian Palm-Swift	*Cypsiurus balasiensis*	35	CO	Re
Order Cuculiformes						
11	Cuculidae	Greater Coucal	*Centropus sinensis*	9	R	Re
12		Common Hawk Cuckoo	*Hierococcyx varius*	9	R	Re
13		Asian Koel	*Eudynamys scolopaceus*	31	CO	Re
Order Gruiformes						
14	Rallidae	White-breasted Waterhen	*Amaurornis phoenicurus*	84	CO	Re
15		Grey-headed Swamphen	*Porphyrio porphyrio*	89	CO	Re
16		Common Moorhen	*Gallinula chloropus*	32	CO	Re
17		Eurasian Coot	*Fulica atra*	28	FC	Re
18		Gray Francolin	*Francolinus pondicerianus*	51	CO	Re
Order Ciconiiformes						
19	Ciconiidae	Asian Openbill Stork	*Anastomus oscitans*	134	CO	Re
Order Pelecaniformes						
20	Ardeidae	Black-crowned Night Heron	*Nycticorax nycticorax*	13	FC	Re
21		Indian Pond Heron	*Ardeola grayii*	64	CO	Re
22		Purple Heron	*Ardea purpurea*	10	R	LM
23		Little Egret	*Egretta garzetta*	30	FC	Re
24		Cattle Egret	*Bubulcus ibis*	62	CO	Re

25		Intermediate Egret	*Ardea intermedia*	16	FC	Re
26		Great Egret	*Ardea alba*	33	CO	Re
27	Anhingidae	Oriental Darter *** (NT)**	*Anhinga melanogaster*	34	CO	Re
28	Threskiornithidae	Black-headed Ibis * **(NT)**	*Threskiornis melanocephalus*	12	FC	M
Order Suliformes						
29	Phalacrocoracidae	Little Cormorant	*Microcarbo niger*	93	CO	Re
Order Charadriiformes						
30	Charadriidae	Little Ringed Plover	*Charadrius dubius*	4	R	LM
31		Yellow-wattled Lapwing	*Vanellus malabaricus*	18	FC	Re
32		Red-wattled Lapwing	*Vanellus indicus*	54	CO	Re
33	Jacanidae	Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	20	FC	Re
34		Bronze-winged Jacana	*Metopidius indicus*	46	CO	Re
35	Scolopacidae	Common Sandpiper	*Actitis hypoleucos*	14	FC	Re
Order Accipitriformes						
36	Accipitridae	Shikra	*Accipiter badius*	21	FC	Re
37		Black-winged Kite	*Elanus caeruleus*	25	FC	Re
38		Black Kite	*Milvus migrans*	82	CO	Re
39		Brahminy Kite	*Haliastur indus*	28	FC	Re
Order Falconiformes						
40	Falconidae	Common Kestrel	*Falco tinnunculus*	3	R	LM
Order Strigiformes						
41	Strigidae	Barn Owl	*Tyto alba*	5	R	Re
42		Spotted Owlet	*Athene brama*	22	FC	Re
Order Bucerotiformes						
43	Upupidae	Eurasian Hoopoe	*Upupa epops*	13	FC	Re
44	Bucerotidae	Indian Grey-Hornbill	*Ocyceros birostris*	38	CO	Re
Order Piciformes						
45	Picidae	Black-rumped Woodpecker	*Dinopium benghalense*	7	R	LM
46	Megalaimidae	Brown-headed Barbet	*Psilopogon zeylanicus*	10	R	Re
47		Coppersmith Barbet	*Psilopogon haemacephalus*	15	FC	Re
Order Coraciiformes						
48	Meropidae	Blue-tailed Bee-eater	*Merops philippinus*	25	FC	Re
49		Asian Green Bee-eater	*Merops orientalis*	21	FC	Re
50	Coraciidae	Indian Roller	*Coracias benghalensis*	35	CO	Re
51	Alcedinidae	Common Kingfisher	*Alcedo atthis*	16	FC	LM
52		Pied Kingfisher	*Ceryle rudis*	13	FC	LM
53		White-throated Kingfisher	*Halcyon smyrnensis*	36	CO	Re
Order Psittaciformes						
54	Psittacidae	Alexandrine Parakeet *** (NT)**	*Psittacula eupatria*	36	CO	Re
55		Rose-ringed Parakeet	*Psittacula krameri*	29	FC	Re
Order Passeriformes						
56	Oriolidae	Indian Golden Oriole	*Oriolus kundoo*	12	FC	Re
57		Black-hooded Oriole	*Oriolus xanthornus*	11	FC	Re
58	Dicruridae	Black Drongo	*Dicrurus macrocercus*	110	CO	Re
59	Laniidae	Brown Shrike	*Lanius cristatus*	11	FC	Re
60		Long-tailed Shrike	*Lanius schach*	6	R	Re
61	Corvidae	Rufous Treepie	*Dendrocitta vagabunda*	18	FC	LM
62		House Crow	*Corvus splendens*	131	CO	Re
63		Jungle Crow	*Corvus macrorhynchos*	58	CO	Re
64	Campephagidae	Small Minivet	*Pericrocotus cinnamomeus*	5	R	LM
65	Ploceidae	Baya Weaver	*Ploceus philippinus*	24	FC	LM
66	Estrildidae	Indian Silverbill	*Euodice malabarica*	59	CO	Re
67		Scaly-breasted Munia	*Lonchura punctulata*	27	FC	Re
68		Tricoloured Munia	*Lonchura malacca*	6	R	LM
69	Passeridae	House Sparrow	*Passer domesticus*	81	CO	Re
70	Motacillidae	Paddyfield Pipit	*Anthus rufulus*	16	FC	Re
71	Alaudidae	Indian Bushlark	*Mirafra erythroptera*	23	FC	Re
72	Cisticolidae	Plain Prinia	*Prinia inornata*	12	FC	Re
73		Ashy Prinia	*Prinia socialis*	31	CO	Re
74		Jungle Prinia	*Prinia sylvatica*	4	R	LM
75		Common Tailorbird	*Orthotomus sutorius*	19	FC	Re
76	Hirundinidae	Barn Swallow	*Hirundo rustica*	25	FC	Re
77	Pycnonotidae	Red-whiskered Bulbul	*Pycnonotus jocosus*	7	R	Re
78		Red-vented Bulbul	*Pycnonotus cafer*	22	FC	Re
79	Leiothrichidae	Jungle Babbler	*Turdoides striata*	106	CO	Re
80	Sturnidae	Asian Pied Starling	*Gracupica contra*	39	CO	Re
81		Common Myna	*Acridotheres tristis*	193	CO	Re
82		Jungle Myna	*Acridotheres fuscus*	19	FC	LM

83	Muscicapidae	Oriental Magpie Robin	*Copsychus saularis*	39	CO	Re
84		Pied Bush Chat	*Saxicola caprata*	44	CO	LM
85		Blue Rock-Thrush	*Monticola solitarius*	1	R	M
86	Nectariniidae	Purple-rumped Sunbird	*Leptocoma zeylonica*	57	CO	Re
87		Purple Sunbird	*Cinnyris asiaticus*	67	CO	Re
88	Irenidae	Jerdon's Leafbird	*Chloropsis jerdoni*	6	R	LM

Despite being an ever-expanding urban landscape, it is interesting that the Silk city harbors a wide range of avian species across various habitats. Species richness and abundance were found to be relatively higher in AG because of the availability of food, shelter, breeding grounds with lesser disturlevels level [37-39]. It can also be attributed that the AG playsa more crucial role affectinging the urban avian community composition of Berhampur [40, 41]. Hereafter the importance of agricultural lands in Berhampur cannot be ignored in maintaining the richest UAC. After AG, the more diverse habitat is FP due to its vegetation variety, which fulfills all the primary requirements of a larger bird community, i.e., requirethe ment of food, resting and nesting sites [5, 11, 17, 42]. Including this FP has high floral diversity, high herb and shrub density, rich woody and vascular plants species richness, and lesser house density compared to other habitats, which is surely affecting the UAC in urban green spaces of the Berhampur city because all the above-mentioned factors are accountable for effecting the UAC greatly on urban landscapes [4, 43-45].

The rich vegetation of FP and AG is the main cause of increasing the insect diversity which attracts more insectivore avian species in these habitats [46-50]. This increased insect diversity eventually resulted in a greater number of insectivore bird species than HS and WL. Henceforth the insectivore birds were found abundantly in our study area. The correlation between AG and FP can be attributed to the availability of sufficient amount food, rich vegetation and the presence of a much similar bird community with dominating insectivore bird species. The domination of insectivore bird species among UAC of Berhampur city can also be explained with the higher number of Passeriformes bird species found here. Because most of the passerines are insectivore in nature [51, 52].

Opposite to this, HS has shown the least species richness than AG and FP because of poor vegetation, higher house density and the disturbances that are going on *viz*. habitat alteration, implementation of rapid development processes, ongoing construction, noise pollution, artificial light pollution, uncontrolled waste disposal and air pollution. All of these factors are also found to be the main reason for richness in any urban area [53, 54]. This clearly suggests that urbanization has a negative effect on the UAC of Berhampur. Hence among other habitats, HS needs more attention in terms of bird species conversation. In order to fulfill that more numbers of eco-friendly development ideasthe , establishment of more sustainable energy consumption methods, proper EIA (Environment Impact Assessment) before proceeding to any urban development programmes should be followed.

The present study also revealed the higher number of certain bird species like Rock Pigeon *Columba livia*, House Crow *Corvus splendens* and Black Drongo *Dicrurus macrocercus* in urban, areas which is a similar finding as compared to certain studies conducted in urban areas of Delhi and Bhubaneswar respectively [4, 11]. Barn Owl *Tyto alba* along with Spotted owlet *Athene brama* are the major nocturnal bird species that we can come across in this city.

The total area of WL in Berhampur is largely constituted by the major waterbodies and the significantly smaller marshes and swampy patches present in this city. The area ofwater bodiesrbodies are hardly ranges from 0.01 to 0.03 sq. km. Hereafter; it is clear that WL has a a lesser area than other habitats in the city. The major waterbwater bodieshave the deficiency of proper breeding and roosting ground and there is also subtla e deficit of food sources throughout the year. Because the watwater bodiese poorly managed and most of the time covered with Water Hyacinth *Eichhornia crassipes*. This contributes to the lower species richness and the lower number of aquatic migratory avian species in the water bodies of this urban landscape. But the number of individuals is relatively higher in WL than in. Thushus WL showed the more value the of evenness index. Because the main compositthe ion of WL avian community consists of the communal roosting or flocking birds like waders, herons and egrets. These birds are generally found gregariously in aggregated colonies with more numbers [5, 55]. Unlike other habitats, this also means the spatial distribution of bird species across WL is even due to the relatively higher abundance. Due to the low species richness and higher abundance than HS and FP, WL showed a completely different a cluster in deaogram and the poor correlation with other habitats of Berhampur. The lower species richness of waterbirds is problematic for the WL because wetland birds are the essentithe al part of food web in maintaining inland aquatic ecosystems [56, 57]. The heterophagous nature of the waterbirds takes them to occupy the top place in the wetland ecosystem [58, 59]. The most common aquatic bird species of WL in Berhampur are Indian Pond Heron *Ardeola grayii*, Grey-headed swamphen *Porphyrio poliocephalus*, White-breasted Waterhen *Amaurornis phoenicurus* and Common Coot *Fulica atra*.

The values of different diversity indices, correlation analysis, and dendrogram give strong evidence that AG is the most suitable habitat for sustaining a larger UAC than other habitats in Berhampur. Afterwards, FP is a more suitable habitat for bir,ds but the least suitable habitat is HS. It is evident that environmental heterogeneity, resource availability along with other atmospheric and anthropogenic disturbances are the main drivers of spatiotemporal distribution of UASD and the correlation among UAC found in different habitat types of Berhampur. The outcomes of this study can be helpful in applying management strategies for more diverse habitats like AG and FP to withstand the regional extinction of the existing UAC. The present study is also helpful in identifying the least diverse habitat types like WL and HS of Berhampur to formulate management plans in order to enrich the UAC of these habitats. This will also help in conserving the habitats of threatened bird species found here. The main management strategies to cope up with the increasing urbanization in Berhampur should include plantation, establishment of uniquely designed urban habitat for rare bird species ensuring the availability of food, shelter, nesting sites, proper habitat threat assessment and needful mitigative measures against the threats.

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